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A CONTRIBUTION TO THE BIOLOGY AND CONTROL OF THE GREEN CITRUS APHID, *Aphis Spiraecola* PATCH

DISSERTATION

PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE GRADUATE SCHOOL OF THE OHIO STATE UNIVERSITY

BY

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A CONTRIBUTION TO

THE BIOLOGY AND CONTROL OF THE GREEN CITRUS APHID, *Aphis Spiraecola* PATCH

By RALPH L. MILLER

TECHNICAL BULLETIN

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*In cooperation with U. S. Department of Agriculture.

A CONTRIBUTION TO THE BIOLOGY AND CONTROL OF THE GREEN CITRUS APHID, *APHIS SPIRAECOLA* PATCH*

By RALPH L. MILLER,
Formerly Assistant Entomologist, Florida Agricultural Experiment Station

The purpose of this bulletin is to discuss in some detail the life history and habits of the green citrus aphid now commonly found in Florida. Special attention is given to the control effected by the natural enemies—predators, parasites and fungous diseases.

Most of the common insecticides available in Florida were used experimentally. All previous publications concerning this insect were reviewed and a bibliography is given at the end of the paper.

The work was carried on at the Citrus Experiment Station at Lake Alfred, Florida, and was a cooperative enterprise between the Florida Agricultural Experiment Station and the State Plant Board.

ACKNOWLEDGMENTS

The writer is indebted to Professor J. R. Watson for his direct supervision and Dr. Wilmon Newell for his many suggestions in regard to the problem. Dr. Herbert Osborn and Dr. R. C. Osburn, both of Ohio State University, offered many helpful criticisms of the work and the paper. Several men in the Bureau of Entomology, United States Department of Agriculture, aided by obtaining the analysis of materials and identifying insects. Many thanks are due the wife of the writer for her aid in preparing the paper for publication.

IDENTITY OF THE APHID

The identity of the green citrus aphid of Florida has been somewhat obscured by a question of synonomy. In 1914, Dr. E. M. Patch *(13)*[1] reported the following—"*Aphis spiraecola* n.n. This species is certainly close to *pomi* and may possibly be a variety but it does not seem safe to place it with that species at present. It is recorded by Professor Gillette as *Aphis spiraeela*

*Presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of the Ohio State University.

[1]Numbers in parentheses (italic) refer to "Literature Cited" in the back of this bulletin.

Schouteden 1910. The antenna is practically the same as with *pomi.* The cornicles in the winged form are shorter than any *pomi* I have taken."

The report of Professor C. P. Gillette *(8)* of which Dr. Patch speaks is as follows—"*Aphis spiraeella* Schouteden Fig. 14 and 15. What I have taken to be this species was a very common louse upon bridal wreath *(Spiraea prunifolia).* Taken at Lansing, very abundant, Geneva, Detroit, Albany, New York City, Washington, Springfield, Webster and Woods Hole. In general appearance resembling closely a small *A. pomi,* was common one year, 1907, on spiraea on the campus of the Agricultural College at Fort Collins but has not been seen in the state since. The antenna is hardly distinguishable from *pomi* except in size." Professor J. J. Davis *(6)* considers *Aphis spiraeella* as found by Professor C. P. Gillette different from *Aphis spiraea* of H. Schouteden *(16).*

In 1923 Dr. Patch *(14)* reported the following—"My own present interpretation of the situation is that we are concerned with one very variable species. That *Spiraea* and not *Pyrus* was the original primary food plant of the species; that the normal cycle is still followed with reference to *Spiraea;* that *Pyrus* with its succulent succession of summer growth (water sprouts, etc.) and its normal overwintering habit has proven satisfactory enough to serve as an all year host; and that the species in the sexual generation is dimorphic, the rather degenerate forms on the apple (with the wingless male) being the modification in the apple race in the sexual generation."

In 1924 Dr. A. C. Baker is reported by Professor J. R. Watson *(22)* as identifying the green citrus aphid as *Aphis spiraecola* Patch. In 1925 Mr. A. N. Tissot *(19)* transferred *Aphis pomi* from apple in Pennsylvania to citrus in Florida and succeeded in getting only 2 of 47 to live to maturity and reproduce while a similar number of the introduced aphids all developed and reproduced abundantly on apple in Florida at the same time and under the same conditions. He states that this may be evidence that the citrus aphid is a new physiological race.

The points on which Dr. Patch separates the two forms are sufficient in the minds of many workers to make the aphids distinct species. Since the two forms are not identical the green citrus aphid is being called *Aphis spiraecola* Patch in this paper.

It is hoped that further work on the biology of this aphid being carried on at Gainesville, Florida, by Mr. A. N. Tissot will aid in definitely settling the matter.

HISTORY AND DISTRIBUTION

Professor J. R. Watson *(20)* states that "this aphid first attracted attention as a citrus pest during the spring of 1923, although it was not until a year later that it was distinguished from the melon aphid. However, its presence in certain groves in the Manatee section as early as the fall of 1922 has been quite definitely established. There is no sure record of its presence on citrus in Florida at an earlier date. There are many records of earlier infestations of aphids but usually such expressions as 'the aphids left the citrus and went to watermelons,' would indicate that the species involved was the melon aphid."

As to the spread of the aphid over the state Professor Watson *(29)* states that it did not seem to follow the main lines of transportation but rather followed the direction of the prevailing winds. This shows that it was not carried so much by vehicles as it was blown by the winds that occur almost continuously. This aphid is now found in northwestern Florida and has been reported from California by Mr. W. W. Yothers *(31)*. Specimens were received from Alabama by Professor Watson in 1926. Mr. R. L. Westmoreland has recently reported it from Honduras where growers say it has been present for at least 10 years. This aphid was recently reported from Cuba by Watson *(26)* and has apparently been there also for some time.

HOST PLANTS

From time to time workers have given host plants for the citrus aphid until at present there is a very extensive list. Among the plants reported by Dr. Edith M. Patch *(14)*, considering *Aphis pomi* and *Aphis spiraecola* identical, are the following:

Polygonum lapathifolium L. ..... Smartweed
Polygonum sachalinense Sacaline ..... Smartweed
Rumex crispus L. ..... Yellow dock
Chenopodium album L. ..... Lamb's quarters
Portulaca oleracea L. ..... Common purslane
Ranunculus acris L. ..... Buttercup
Capsella bursa-pastoris L. ..... Shepherd's purse
Nasturtium palustre L. ..... Marsh cress

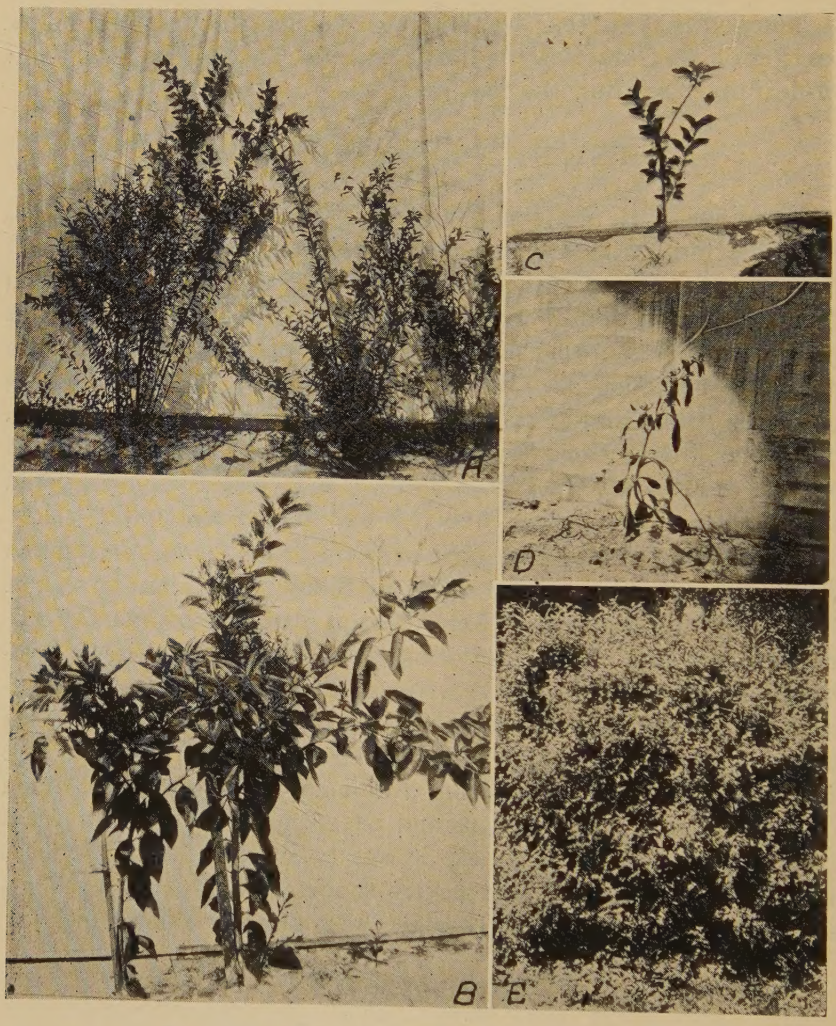

Fig. 107.—Some hosts of the citrus aphid—

A. *Spiraea* sp., bridal wreath. This ornamental shrub furnished aphid food during the entire year.

B. *Citrus* sp. Aphids were found on this host during the entire year. However when groves had periods of complete dormancy no aphids were present.

C. *Pyrus malus*, Apple. Like citrus, the apple is attacked whenever new growth is present, but especially during the spring months.

D. *Gnaphalium* sp., cudweed (several species). This plant grows during the period when citrus trees are dormant, November to April, and is important in carrying the aphids over the winter.

E. *Antigonon leptopus*, coral vine, Rosa-de-Montana. This beautiful vine grows during the entire year, if not killed by frost, but is attacked by the citrus aphid only during the summer and autumn.

Raphanus raphanistrum L. ..... Wild radish
Philadelphus coronarius L. ..... Syringa or mock orange
Philadelphus grandiflorus Willd. .....
Ribes sp. ..... Gooseberry
Amelanchier canadensis L. ..... Shad bush
Pyrus aucuparia L. ..... Mountain ash
Pyrus communis L. ..... Common pear
Pyrus japonica Thumb. ..... Japan quince
Pyrus malus L. ..... Common apple
Spiraea aruncus L. ..... Goat's beard
Spiraea prunifolia Sieb. ..... Bridal wreath
Spiraea salicifolia L. ..... Meadow-sweet
Spiraea van houttei .....
Pisum sativum L. ..... Common pea
Trifolium pratense L. ..... Red clover
Impatiens balsamina L. ..... Garden balsam
Celastrus scandens L. ..... Bitter-sweet
Rhamnus cathartica L. ..... Common buckthorn
Ampelopsis quinquefolia ..... Virginia creeper
Malva rotundifolia L. ..... Common mallow
Aralia racemosa L. ..... Spikenard
Daucus carota L. ..... Wild carrot
Cornus amomum Mill. ..... Silky cornel
Cornus sericea L. .....
Cornus stolonifera Michx. ..... Red-osier dogwood
Forsythia suspensa Vahl. .....
Ligustrum ibota Sieb. .....
Apocynum androsaemifolium L. ..... Spreading dogbane
Asclepias cornuti Dcne. ..... Common milk weed
Galeopsis tetrahit Linn. ..... Common hemp nettle
Plantago major Linn. ..... Plantain
Sambucus canadensis L. ..... Common elder
Viburnum dentatum ..... Arrow-wood
Viburnum opulus var. *americana* ..... Highbush cranberry
Eupatorium perfoliatum L. ..... Thoroughwort, boneset
Eupatorium purpureum L. ..... Joe-Pye weed
Leontodon autumnalis L. ..... Fall dandelion
Matricaria matricarioides P. ..... Common sow-thistle
Taraxacum officinale Weber. ..... Common dandelion

In Florida this aphid has been reported from the following plants:—

Citrus sp. ..... All citrus
Pyrus malus Linn. ..... Apple
Pyrus communis L. ..... Pear
Pyrus japonica Thumb. ..... Japan quince
Pyrus sp. ..... Sand pear
Spiraea sp. ..... Bridal wreath (several sp.)
Asclepias tomentosa Ell. ..... Milkweed
Gnaphalium sp. ..... Cudweed (several sp.)
Solanum sp. ..... Nightshade
Eupatorium capillifolium Small. ..... Dog fennel
Chenopodium ambrosioides D. ..... Mexican tea
Chenopodium album L. ..... Lamb's quarters
Sonchus sp. ..... Sow-thistle
Prunus sp. ..... Wild plum
Eriobotrya japonica Lindl. ..... Loquat
Lactuca sp. ..... Lettuce
Laurocerasus caroliniana (Mill.) Roem.) ..... Cherry laurel
Pereskia aculeata Mill. ..... Lemon vine

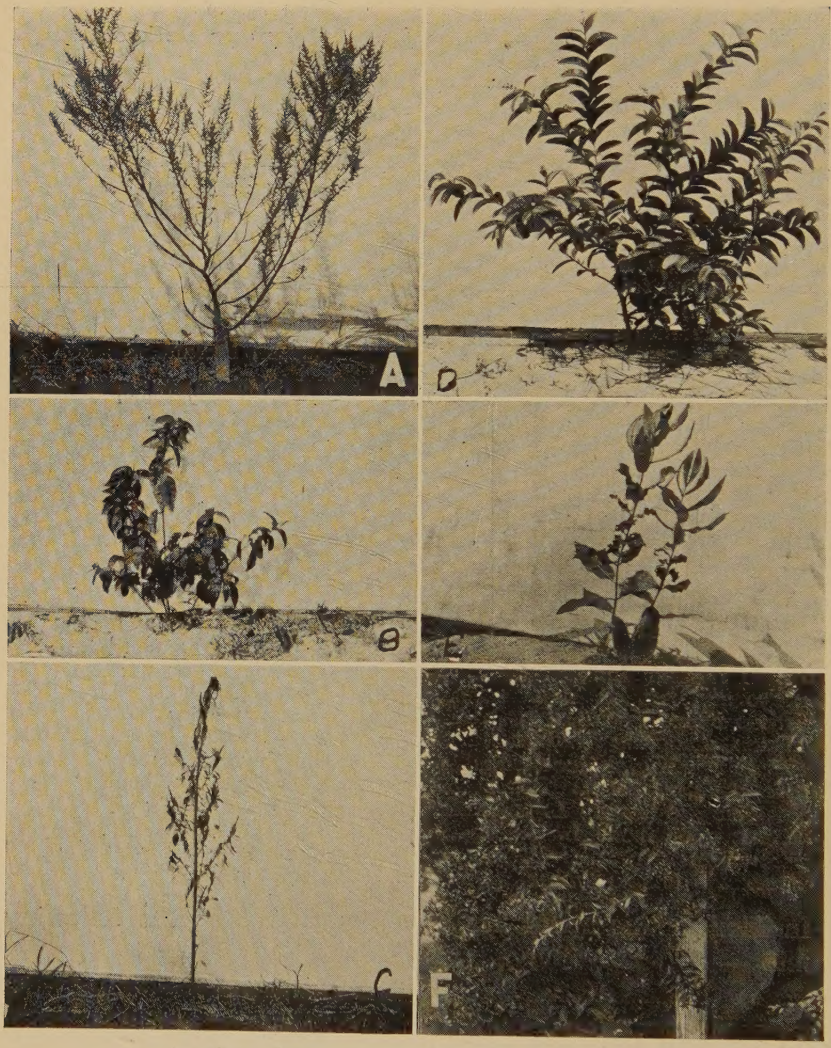

Fig. 108.—More hosts of the citrus aphid—

A. *Chenopodium ambrosioides*, Mexican tea. This plant serves as host for the citrus aphid during the late spring and late autumn months.

B. *Gardenia* sp., night blooming jasmine. This ornamental is an occasional citrus aphid host plant but is attacked most severely during the spring.

C. *Amaranth* sp., red root or pigweed. This common weed is occasionally found with a very light infestation of aphids during late spring.

D. *Pisidium guayava*, guava. Citrus aphids are occasionally found to feed on this plant but do not seem to thrive on it.

E. *Asclepius tomentosa*, milkweed. This common grove weed grows during the spring and is attacked by the aphid during late spring and early summer.

F. *Pereskia aculeata*, lemon vine. Occasionally attacked.

Fig. 109.—Other hosts of the citrus aphid—

A. *Cryptostegia grandiflora*, rubber vine. During late spring this ornamental is often severely attacked by the citrus aphid.

B. *Bidens leucantha*, Spanish needle. The flowers and flower stems of this common weed are very severely attacked during late spring or fall.

C. *Eupatorium capillifolium*, Dogfennel. Occasionally attacked.

D. *Rumex crispus*, yellow dock. This plant grows during the spring and is an occasional aphid host.

E. *Phytolacca decandra*, pokeweed. Although the writer was not able to rear a complete generation of aphids on this plant, young were often deposited on it.

Phytolacca decandra L.	Pokeweed
Erechtites hieracifolia L.	Fireweed
Malus angustifolia (Ait.) Michx.	Crab apple
Persea persea (L) Cockrell	Avocado

The writer has taken the citrus aphid from the following additional host plants in Florida:—

Amaranthus sp.	Amaranth, careless weed
Rumex crispus L.	Yellow dock
Rumex acetosella L.	Horse sorrel
Antigonon leptopus Hook and Arn.	Coral vine, Rosa-De-Montana
Cryptostegia grandiflora R. Br.	Rubber vine
Bidens leucantha L. (Willd.)	Spanish needle
Gardenia sp.	Jasmine
Psidium guayava	Guava

In the case of citrus trees only very young growth is attacked; that is, growth under three weeks of age. In the case of other plants there is not as much preference shown but leaves and especially flowering heads are attacked. Most host plants, except spiraea, seem to be temporary or overflow host plants.

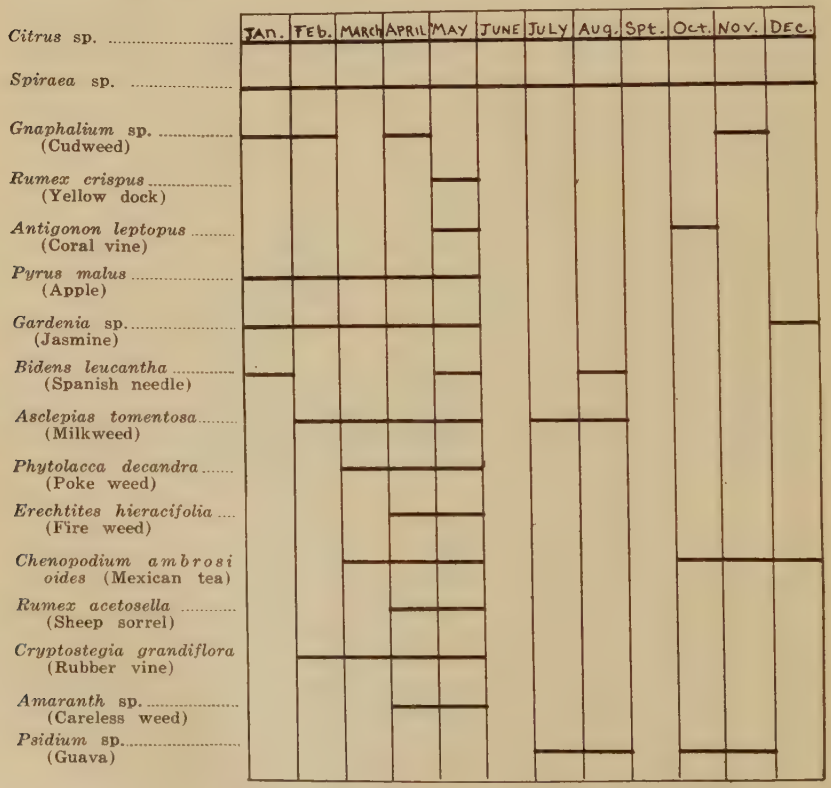

Fig. 110.—Seasonal host plants of the green citrus aphid.

They are attacked only when the aphids become concentrated on citrus and must leave because it hardens. In Figs. 107, 108 and 109 are shown a group of the most common aphid host plants.

Fig. 110 shows the seasonal host plants of the citrus aphid. This is based on weekly observations made at Lake Alfred, Florida. A plant was considered a host when the adult had deposited young thereon or when only young were found.

Table I shows the life history of *Aphis spiraecola* on various host plants. Mature females, taken from citrus, were allowed to deposit young, the adults were removed and the young observed until death. All life history work was carried on in cloth bags in the nursery or grove and representative individuals were chosen in each case.

VARIETIES OF CITRUS ATTACKED

When the aphid first appeared it was the opinion of many growers and workers that the tangerine and the Temple orange were the choice of all citrus host plants. Further work and observations have indicated that this is not entirely true. The aphid can live and reproduce quite well on grapefruit which was at first thought to be immune from attack. The tangerine is most severely attacked because it grows continually and later in the spring. It is just beginning to grow well when orange and grapefruit growths begin to harden. For this reason the winged aphids leave the hardening growth only to concentrate on the tender, succulent tangerine and cause severe damage. Grapefruit is not attacked, for it grows quite early, hardens its growth quickly and then remains dormant. If for some reason grapefruit grows late in the spring or otherwise out of season it may be severely attacked. During the spring of 1927 following the freeze many grapefruit groves in the vicinity of Lake Alfred were growing irregularly and these were quite severely attacked by aphids.

Instead of naming varieties that are severely attacked one can say that any variety which grows continuously and late in the spring will be severely attacked. Those which harden their growth early in the spring are not attacked. For example, the continuously growing Temple orange is almost always infested while grapefruit is very seldom attacked. Rough lemon, and especially sour orange and trifoliata trees are only slightly attacked. Kumquats are not attacked.

TABLE I.—Effect of Different Host Plants on the Life History of *Aphis Spiraecola* Patch.

b—born; v—development; numbers—young deposited; d—died.

March 1927	*Citrus* sp. (Orange, etc.)	*Spiraea* sp. (Bridal wreath)	*Gardenia* sp. (Jasmine)	*Pyrus malus* (Apple)	*Gnaphalium polycephalum* (Cudweed)	*Chenopodium ambrosioides* (Mexican tea)	*Asclepias tomentosa* (Milkweed)	*Amaranthus* sp. (Careless weed)	*Rumex acetosella* (Horse sorrel)	*Rumex crispus* (Yellow dock)	*Bidens leucantha* (Spanish needle)	*Antigonon leptopus* (Coral vine)	*Brechtites hieracifolia* (Fire weed)	*Phytolacca decandra* (Pokeweed)	*Psidium* sp. (Guava)	*Persea* sp. (Avocado)	*Eupatorium capillifolium* (Dog fennel)
days																	
1	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	*	b
2	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v		v
3	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v		v
4	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v		v
5	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v		v
6	2	v	v	v	v	v	v	v	v	v	v	v	v	v	v		v
7	3	v	v	v	v	v	v	3	v	v	v	v	5	v	v		v
8	4	v	v	8	v	v	1	1	v	1	1	v	3	v	v		v
9	8	1	4	6	2	2	1	2	1	1	2	1	6	v	v		v
10	5	2	4	4	1	3	3	2	2	0	1	1	8	v	v		v
11	12	2	3	7	3	1	3	2	2	d	d	1	10	v	v		v
12	8	0	2	4	3	1	4	0	1			d	10	5	v		1
13	6	5	3	7	2	2	1	d	0				5	3	v		0
14	4	2	4	4	p	0	4		d				3	2	d		1
15	5	2	7	4		4	1						2	0			d
16	8	1	1	9		0	3						d				
17	1	2	1	1		0	0										
18	d	1	1	2		d	d										
19		2	d	11													
20		1		0													
21		0		d													
22		0															
23		1															
24		d															

*All died in three attempts.

DAMAGE CAUSED BY THE CITRUS APHID

The most noticeable damage of the citrus aphid is that of leaf curling. One or two aphids feeding on the underside of the leaf, as is their habit, will cause it to curl slightly, while a larger number will cause it to curl tightly. After a leaf has been curled it loses its oily appearance and appears dwarfed. A tree with many such leaves seems greatly stunted. (See Fig. 111.) This curling causes the leaf surface to be reduced or of poor quality for carrying on the necessary processes. It causes a small weak

TABLE II.—Effect of Aphids on Tangerine Blossoms and Young Fruit.

Severely Attacked by Aphids		Free From Aphids	
Blossoms	Fruit Set	Blossoms	Fruit Set
3	0	15	4
3	1	16	2
5	2	4	0
7	1	10	3
10	1	13	1
11	0	5	2
2	2	2	0
16	1	7	1
4	1	10	5
3	0	16	1
10	2	10	4
19	2	14	2
17	0	3	1
11	1	7	2
5	0	6	0
3	0	....	..
129	14	138	28
10.9% Set fruit		20.3% Set fruit	

bloom without any leaves to appear the next season. Curled leaves on a tree afford a well protected hiding place for scale. Most scale crawlers are negatively phototropic and hunt curled leaves or similar dark places to attach themselves. Dr. F. R. Cole *(4)* estimated that the citrus aphid caused four million dollars damage to citrus during 1924.

When blossoms or very young fruit are attacked by aphids much of the fruit will drop. Professor J. R. Watson states—"A heavy infestation of aphids materially reduces or entirely prevents the setting of fruit." Table II shows the effect of aphids on tangerine blossoms and young fruit.

Damage caused by the citrus aphid appears to be only temporary, for twigs with severely curled foliage will often produce straight growth at the next flush if kept free from aphids. (See Fig. 111.) Fortunately for the grower there is usually only one flush of growth of the year that is severely attacked by aphids.

LIFE HISTORY

Probably the first life history work in Florida on the citrus aphid was done by Mr. A. H. Beyer *(2)* during the spring of 1924. He gives the following summary—"Viviparous females were used in starting these studies as no eggs or stem mothers were found. The reproductive period of the female varied, during the time of these studies, from 2 to 11 days with an average of five young per day. The longevity of the females used ranged from 3 to 21 days. In most cases death was due to natural causes. We must, however, take into consideration the conditions of temperature and humidity which would have some influence on the mortality, as the experiments were conducted under a tent where the temperature ranged from 85 to 98 degrees.

"The maximum number of young produced by a single female was 61 and the minimum was 8. The birth rate was highest in the early life of the female and the largest number of young were brought forth during the morning hours. The percentage of winged individuals produced during this series of experiments ranged from 45 to 69."

Mr. A. N. Tissot *(18)* working at Gainesville, Florida, and rearing aphids out of doors in cloth bags (the type after which the writer has patterned his), states that the development period of the aphid ranged from 13 days in March to 6.7 days

in the first half of May. In November the average total young produced per female was 34 while in April it was 70.8. The daily rate of reproduction was 2.7 young per female in November and 4.1 during April. He also states that the aphids develop better at the temperature during April but do not develop as well at higher or lower temperatures.

Fig. 111.—Showing damage by citrus aphid, and materials used in life history work. A. Normal citrus leaves. B. Badly curled citrus leaves. C. Damaged twigs showing new growth. D. Twig of tender, susceptible growth. E. Bags used in life history work. F. Nursery used in life history work.

Beginning in August, 1926, the writer began a first born generation series life history study of *Aphis spiraecola.* This work was carried on entirely out of doors. The aphids were caged in cloth screen bags on tender growth of nursery trees. (See Fig. 111.) Very tender citrus twigs were used as host plants during the entire year except immediately after the freeze in January, 1927, when they were not available. At this time spiraea was used and as soon as growth appeared on the citrus the aphids were again placed on that.

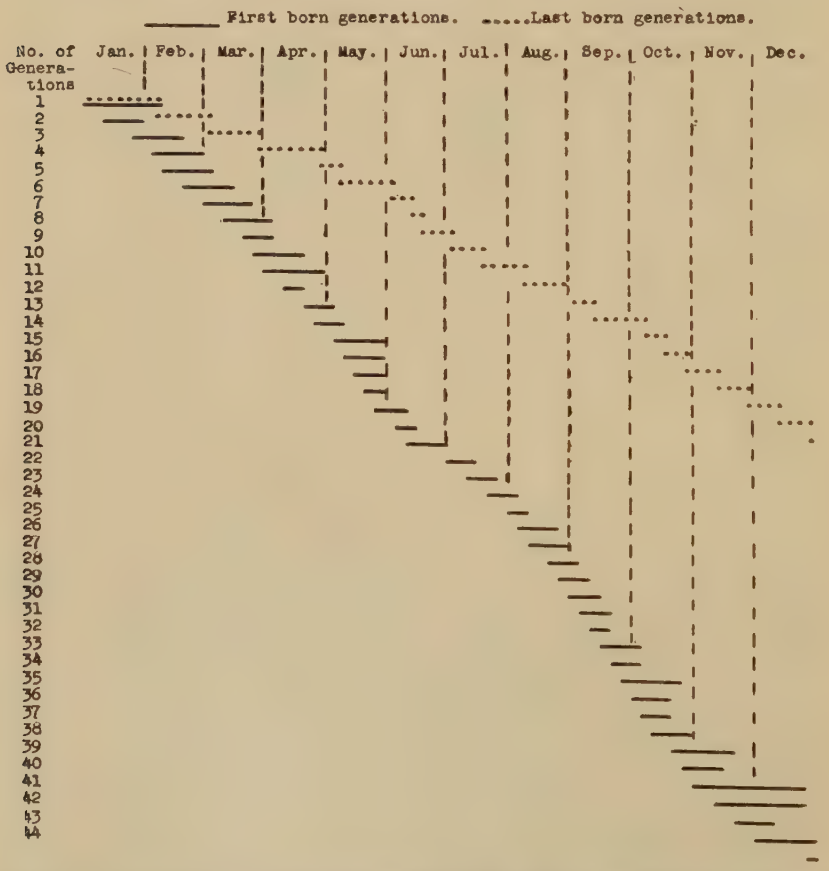

Fig. 112.—A record of the aphid generations which occurred in a study at Lake Alfred, Florida, from August, 1926, to July, 1927.

To begin the work, a robust wingless female was chosen. Her first born young were allowed to mature in captivity. At their maturity one was chosen and its first born were again reared to maturity, etc. The last born generations are not complete

records of one individual but when the last born of one individual were produced another generation was begun, which method gave a series of last born generations extending over the entire year.

TABLE III.—Variation in Maturity, Reproduction and Length of Life of Aphids.

b—born; v—developmental period; numbers—young produced; d—died.

No. of Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	b	b	b	b	b	b	b	b	b	b	b	b
2	v	v	v	v	v	v	v	v	v	v	v	v
3	v	v	v	v	v	v	v	v	v	v	v	v
4	v	v	v	v	v	v	v	v	v	v	v	v
5	v	v	v	v	v	v	v	v	7	v	v	v
6	v	v	v	v	v	v	v	v	6	v	v	v
7	v	v	v	v	v	v	v	v	5	v	v	v
8	v	v	v	5	v	v	3	2	5	3	v	v
9	v	v	v	5	6	v	3	0	11	0	3	5
10	v	v	v	9	4	3	2	0	5	3	6	5
11	v	v	v	3	3	0	0	1	5	1	2	6
12	v	7	4	1	4	d	1	d	7	6	0	6
13	v	4	3	1	1	.....	3	.....	1	1	5	6
14	v	5	3	6	5	.....	2	.....	d	4	4	5
15	v	6	6	1	4	.....	0	.....	.....	4	0	4
16	1	5	7	1	1	.....	d	.....	.....	3	4	5
17	0	5	3	4	3	.....	.....	.....	.....	0	6	3
18	0	6	8	0	0	.....	.....	.....	.....	d	3	7
19	0	0	8	2	4	.....	.....	.....	.....	.....	2	6
20	2	3	6	2	1	.....	.....	.....	.....	.....	1	4
21	1	4	5	0	4	.....	.....	.....	.....	.....	0	6
22	1	5	6	1	2	.....	.....	.....	.....	.....	1	4
23	5	7	1	0	0	.....	.....	.....	.....	.....	1	1
24	0	6	d	d	0	.....	.....	.....	.....	.....	0	2
25	1	3	.....	.....	0	.....	.....	.....	.....	.....	0	2
26	2	d	.....	.....	d	.....	.....	.....	.....	.....	0	0
27	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	2
28	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0
29	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0
30	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	d	0
31	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
32	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
33	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
34	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	d
35	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
36	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
37	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
38	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
39	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
40	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

There is considerable variation in the time to mature, rate of reproduction, length of life and total number of young pro-

duced during different times of the year as shown in Table III. Representative individuals born each month were chosen.

As will be seen from the life history work the aphid passes the entire season in the active stage at Lake Alfred, Florida. So far as the writer has been able to ascertain, no male forms or oviparous forms appear and no eggs are deposited. At Gainesville, Florida, eggs were deposited rather abundantly on spiraea. Mr. A. N. Tissot *(18)* found in 1925-26 that these eggs did not hatch while in 1926-27 many hatched quite successfully. No eggs were ever found on citrus.

Nymphal Period.—The nymphal period was quite variable during the year. It was shortest during the month of September (4 days), and longest during the monhs of January (16 days), and June (13 days). The average for the year was 6.93 days for 198 females.

Reproduction.—The highest rate of reproduction occurred in September. An average of 7.3 young per day per female occurred during the week of September 13 at an average temperature of 79°. Another point of high rate of reproduction was reached in February when an average of 6.8 young per female per day was found during the week of February 14 at an average temperature of 70°. The lowest rate of reproduction was found during January but reproduction during the remainder of the year, with certain exceptions, was quite low also. The daily reproduction for the year was 2.98 young per female. The greatest number of nymphs deposited on one day by one female was 16. The total number of young produced by one female was quite variable, ranging from 1 to 103. The average number of young produced per female for the year was 29.11 for 198 females.

Number of Generations.—From August 18, 1926 to August 17, 1927 the citrus aphid was reared through 44 successive first born generations and 20 successive last born generations. The average number of young produced by females in each generation was quite variable, ranging from 71.6 in the 21st generation in February to .8 for the 37th generation in June.

Longevity.—The length of life was found to range from an average of 11.8 days during late May or early June to 33 days during January. The greatest length of life known was 49 days. The average length of life for 198 females during the year was 16.7 days.

Life History of Winged Forms.—There is usually a difference in the life history of winged forms for in most cases the nymphal period is longer and the rate of reproduction somewhat less than that of the wingless forms.

TABLE IV.—Life History of Winged and Wingless Aphids.

b—born; v—developmental stage; numbers—young produced; d—died.

Days of the Month	Wingless Females				Winged Females			
	November		March		November		March	
1	b	b	b	b	b	b	b	b
2	v	v	v	v	v	v	v	v
3	v	v	v	v	v	v	v	v
4	v	v	v	v	v	v	v	v
5	v	v	v	v	v	v	v	v
6	v	v	v	v	v	v	v	v
7	v	v	v	v	v	v	v	v
8	v	v	2	3	v	v	v	v
9	v	v	3	4	v	v	v	v
10	v	v	4	5	v	v	v	v
11	v	v	8	5	v	v	4	4
12	v	v	5	7	v	v	0	5
13	v	v	12	2	v	v	0	0
14	2	2	8	9	v	v	2	1
15	6	5	6	8	v	v	1	3
16	5	3	4	4	v	2	3	3
17	8	5	5	5	v	2	3	2
18	5	8	8	5	1	4	4	1
19	5	5	d	5	3	4	4	5
20	5	5	.....	0	1	3	2	4
21	12	4	.....	4	7	4	2	2
22	4	3	.....	1	5	0	6	1
23	6	5	.....	2	0	0	0	6
24	8	6	.....	0	1	1	3	4
25	8	3	.....	0	d	0	3	1
26	4	5	.....	0	.....	4	4	d
27	4	3	.....	0	.....	4	d	.....
28	4	4	.....	0	.....	4	.....	.....
29	3	1	.....	0	.....	0	.....	.....
30	1	d	.....	d	.....	d	.....	.....
31	d	.....	.....	.....	.....	.....	.....	.....

OCCURRENCE OF WINGED FORMS

Observations made during the year showed that winged aphids were always present; however they were most abundant during late April and May. Whenever one could find a tree growing continuously or a tree with hardening growth, he was sure to find a few winged aphids present. This observation led the writer to believe that the development of winged forms could

Fig. 113.—Apparati used in testing reactions of the citrus aphid—

A. Phototropic apparatus. The top of the trough was covered with various grades of material as follows: open, wire screen, single cheese cloth, single sheeting, double sheeting and cardboard. Water was run over the tube to maintain a constant temperature.

B. Humidity apparatus. The test tubes contain various grades of sulphuric acid from pure to water.

C. Thermotropic apparatus. The heat was generated by the alcohol lamp and salted ice was used for the low temperature. This apparatus was set up in a dark room.

D. Chemotropic apparatus. Aphids were liberated in the center of the circle and the whole apparatus was set up level in the dark room.

be correlated with abundance or kind of food, so the following counts were made.

During the process of rearing aphids for life history work through an entire year few winged forms appeared. It was observed however that when a large number of young aphids were allowed to mature on one rather hard twig, many winged forms appeared but when some from the same lot were allowed to mature singly on tender foliage they were always wingless.

Of 198 aphids produced by wingless stem mothers and reared to maturity singly on tender foliage, 190 were wingless and 8 winged. Of 238 aphids produced by wingless stem mothers and reared to maturity in a group on one partly hardened twig, 152 were winged and 86 were wingless.

Seven young, deposited by a wingless female on a tender citrus leaf 1 x 2 cm., matured as wingless females, while of 30 aphids from the same female, placed on a leaf of similar size and condition, 22 matured with wings and 8 were wingless. As indicated in the examples above, it seems that the crowding of aphid nymphs during development causes the production of winged forms. Twenty aphids deposited by winged females were allowed to mature singly on tender foliage and all were wingless. Aphids reared on *Bidens leucantha, Rumex crispus* and *Eupatorium capillifolium* produced many winged forms, while those reared on *Pyrus malus* and *Erechtites hieracifolia* produced only occasional winged forms.

REACTIONS OF THE CITRUS APHID

Geotropism.—When aphids were scattered over the inside of a one-inch glass tube, two feet long, stoppered at both ends and the tube hung in a vertical position in a dark room, they gave no marked reaction. When all of the aphids were placed at the bottom of the tube a count three hours later showed that many had crawled to the top.

Phototropism.—When aphids were scattered over the inside of a glass tube (placed under running water at 85° F.) part of which was unshaded, part shaded by 24 mesh copper wire screen, part by cheesecloth, part by unbleached sheeting, double sheeting and cardboard, the aphids left the darkness under the cardboard and the bright light in the open to become markedly more concentrated under the cheesecloth. See Fig. 113. This experiment was conducted out of doors between the hours of 1 and

5 P.M. on July 10. The sun was very bright. Table V shows the reaction to the various degrees of light intensity. The numbers represent the actual number of aphids found at various places in the tube as the experiment progressed.

TABLE V.—Reaction of Aphids to Light.

Material Used	Inches	2:15 P.M.	3:45 P.M.	4:45 P.M.	Total
Cardboard (Almost total darkness)	1	69	10	11	
	2	37	8	8	
	3	43	17	20	
	4	33	30	27	66
Double Sheeting	5	50	45	43	
	6	50	75	68	
	7	61	60	63	
	8	51	55	55	229
Single Sheeting	9	47	53	43	
	10	36	52	48	
	11	43	60	57	
	12	47	50	61	209
Cheese Cloth	13	51	66	70	
	14	40	91	96	
	15	46	89	83	
	16	49	80	79	328
Screen	17	48	85	90	
	18	40	67	59	
	19	47	55	47	
	20	56	41	31	227
Unshaded	21	61	8	11	
	22	30	5	7	
	23	47	10	20	
	24	55	25	40	78
		1137	1137	1137	1137

Thermotropism.—When aphids were distributed over the inside of a glass tube and this tube immersed in a water bath varying in temperature from 64° C. at one end to 0° C. at the other, the results were as given in Table VI.

The aphids became most concentrated at a temperature between 80.5 and 85° F. which corresponds quite closely with the temperature of maximum production (79°F.).

TABLE VI.—Reaction of Aphids to Temperature.

Temperature	Inches	Aphid Distribution	
64°C (147°F)	1	killed	
	2	"	
	3	"	The high temperature was
	4	"	
	5	0	maintained by an alcohol
	6	0	
	7	0	lamp and the low tempera-
	8	1	
	9	5	ture by salted ice. The
34°C (93°F)	10	4	
	11	8	temperatures were recorded
	12	10	
	13	15	by the thermometers inside
	14	15	
	15	12	the glass tube. The whole
22°C (72°F)	16	8	
	17	7	apparatus was set up in an
	18	6	
	19	1	absolutely dark room.
	20	5	
	21	2	
	22	0	
	23	0	
0°C (32°F)	24	0	

Chemotropism.—In order to observe the reaction of the citrus aphid to its various host plants the apparatus was set up as shown in Fig. 113. The cardboard was 16 inches square and the twigs were placed six inches from the center ring. An approximately equal weight of twig was used in each case. All tests were conducted on a level shelf in the dark room. All aphids were liberated in the central ring and observations were made at various times later.

Table VII shows the percent of aphids on the various plants at different times of observations. All stages and both winged and wingless individuals were used with apparently similar reactions. It will be noticed that the total number of aphids on the plants decreased as the plants wilted.

Thigmatropism.—When the citrus aphid was touched with a brush or the point of a stick it became nervous and began to move about. When aphids were to be transferred from one plant to another it was quite easy to get them to loosen their beaks by stroking them on the side with a camel's hair brush.

Effect of Humidity.—Five test tubes were prepared, using distilled water in one and various dilutions of sulphuric acid to pure acid. By this method various grades of humidity were obtained.

TABLE VII.—Reaction of Aphids to Different Host Plants.

Hrs. After Starting	Total Aphids On Plants	Orange	Mexican Tea	Tangerine	Guava	Spiraea	Poke	Bidens	Paper
				A					
1½	149	46%	1%	11%	11%	2%	12%	6%	11%
4	221	51	2	12	8	1	13	4	9
6	195	48	4	14	7	4	11	9	3
22	102	72	1	5	6	4	10	2	0
				B					
1½	135	32%	2%	12%	12%	5%	24%	10%	3%
4	191	28	2	13	8	15	20	10	4
6	148	30	8	20	6	6	20	7	3
22	78	43	3	28	6	6	5	9	0
				C					
1½	142	14%	4%	9%	20%	15%	30%	7%	1%
4	158	17	5	18	17	19	18	6	0
6	214	18	2	10	9	44	12	3	2
22	88	50	3	26	7	4	7	0	3

Ten cc. of the proper mixture was put into each tube and a loose cotton plug pushed down half-way in the tube. Aphids were then placed on top of the cotton plug and a cork was used to close the mouth of the tube. See Fig. 113. The results are shown in Table VIII.

TABLE VIII.—Reaction of Aphids to Humidity.

Dilution of Acid	Percent of Humidity	Number Aphids Used	Number Aphids Dead at End of					
			12 Hrs.	16 Hrs.	20 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.
Water	100	125	0	0	0	50%	75%	100%
¼	85%	125	0	35%	85%	95%	100%	.....
½	38%	125	15%	50%	90%	100%	.....	.....
¾	4%	125	25%	75%	95%	100%	.....	.....
Acid (conc.)	0%	125	75%	100%	.....	.....	.....	.....

No aphids lived more than 48 hours, but those in 100 percent humidity lived three times as long as those in 0 percent humidity.

INSECTS FEEDING ON HONEYDEW

Among the insects found associated with the citrus aphid is a group that feeds on the honeydew and has no effect on the aphid itself other than helping to keep the colony in a sanitary condition. The following list of insects comprises those taken by sweeping twigs quite heavily covered with honeydew.

Diptera—(Flies)

Cochliomyia macellaria Fab.	Screw worm fly
Tropidia albistylum Macq.	Syrphus fly
Musca domestica Linn.	House fly
Graphomyia maculata Scop.	
Tabanus americanus Forster	Horse fly
Volucella esuriens Fabr.	
Sarcophaga bullata Parker	Flesh fly
Sarcophaga helicis Towns.	Flesh fly
Sarcophaga sp.	Flesh fly

Coleoptera—(Beetles)

Stephanucha areata Fabr.
Euphoria sepulchralis Fabr.
Cyphon variabilis Thunb.
Monocrepidius vespertinus Fab.
Mordellistena comata Lec.

Hymenoptera—(Wasps and Ants)

Vespula carolina Linn.	Red wasp
Polistes pallipes Lep.	Red wasp
Stictia carolina Fabr.	
Sceliphron caementarium Drury	Mud dauber
Solenius (Hypocrabro) decemmaculatus Say	
Hoplisus (Hoplisoides) sp. near *denticulatus* Pack.	
Tachytes sp.	
Dasymutilla vesta Cress.	Velvet ant
Dasymutilla occidentalis L.	Velvet ant
Solenopsis geminata Fab.	Ant
Componotus abdominalis floridanus	Buckley—Ant
Camponotus socius Roger	Ant
Dorymyrmex pyramicus var. *flavus*	McCook—Ant

NATURAL AGENCIES TENDING TO CONTROL THE CITRUS APHID

Meteorological Factors.—In many instances when trees are heavily infested with aphids a dashing rain will wash great numbers of them to the ground where they will be destroyed *(27)*. This is especially true when the rain is accompanied by a wind. During the hurricane of September, 1926 many groves in the vicinity of Lake Alfred were almost entirely freed of aphids. The washing of the rain and the whipping of the wind knocked the aphids off and killed them.

A temperature of 26° F. did not kill citrus aphids in the field but all new citrus growth was killed and the aphids starved. During the hot weather in May, 1927, when a temperature of 103° F. was reached the aphids died quite young. This condition of temperature was probably made more severe by the accompanying drought.

Cultural Factors.—Any method or time of cultivation, pruning, irrigation, drainage or fertilization that causes the citrus trees to grow continuously will allow the aphids to grow and reproduce continuously and attack all new growth as soon as it appears. Growers should endeavor to get a flush of growth early in the spring, and then harden the growth up to prevent late attacks by the aphid. Eradication of the common weed host plants will greatly aid in control of the citrus aphid. As is the case with most insects, much can be done by way of prevention of infestation by proper cultivation and grove management.

Biological Factors.—In referring to the natural enemies of the citrus aphid, Dr. F. R. Cole *(4)* states, "The natural enemies of this citrus aphid are of more than usual interest because so far as we have observed there are few true parasites. Practically all control of the aphid by insect enemies during 1924 was accomplished by predators. The predators of importance belong to three orders of insects, Neuroptera, Coleoptera and Diptera. The usual enemies of aphids are found in Florida and the Coccinellid beetles are probably of most importance, closely followed by the syrphid flies, and lacewings being a minor factor in control."

Among the predators that Dr. Cole named were the following: Trash bugs *(Chrysopa* sp.) or green lacewings, the ladybeetles—*Olla abdominalis* var. *sobrina* Csy., the twice-stabbed *(Chilocorus bivulnerus* Muls.), the convergent *(Hippodamia convergens* Guer.), the blood-red *(Cycloneda sanguinea* Linn.) and several species of *Scymnus,* small black ladybeetles. Two species of syrphus flies, *Baccha lugens* Loew and *Baccha clavata* Fab., were found as well as a species of Agromyzidae, *Leucopis americana* Malloch. He also states that the syrphus fly larvae were attacked by a hymenopterous parasite, *Pachyneuron siphonophorae* Ashm.

Professor J. R. Watson and Mr. A. H. Beyer *(23)* give practically the same group of predators with a few additional as follows: Australian ladybeetle *(Novius cardinalis)* and the hymenopterous parasite, *Lysiphlebus testaceipes.* It is stated that this parasite is not able to emerge from the citrus aphid. Yothers *(31)* reported the finding by Dr. E. W. Berger of a fungous disease (probably *Empusa fresenii* Nowak.). Watson *(24)* reports this fungus as effecting a good control during the spring of 1925. In his bulletin "Citrus Insects and Their Control," Professor Watson discusses the life history of some of the common predators as worked out by Mr. W. L. Thompson who also added two syrphus flies, *Syrphus wiedmanni* Johnson and *Allograpta obliqua* Say., to the list.

In a later paper, Dr. F. R. Cole *(5)* gives a rather complete list of the predators and also states that the hymenopterous parasite is quite efficient.

The writer made many observations as to the appearance, abundance, life history, feeding habits and natural enemies of the aphid predators and parasites and the results of this work are shown in the following discussion. The natural enemies of

the aphid are quite numerous and are scattered among several groups of insects.

PREDATORS

ORDER=COLEOPTERA
FAMILY=COCCINELLIDAE
Cycloneda sanguinea Fab.
(Blood-red Ladybeetle)

This small red beetle is the most abundant of all ladybeetle predators at Lake Alfred. It was found that the masses of yellow, cigar-shaped eggs hatch in three to five days. The larvae eat aphids at the rate of 16 per day for 10 days or two weeks, then pupate. The pupal stage lasts from four to six days. The adult has been kept alive in captivity for over 50 days and eats an average of 65 aphids per day. One can find this predator during the entire year in the adult stage and in the larval stage during the entire year except January. The efficiency of this predator is probably greatly impaired by its own parasites which were found to be quite abundant during the spring but scarce during the remainder of the year. The parasites reared from these larvae are *Homalotylus terminalis* Say. and *Tetrastichus blepyri* Ashmead.

Fig. 114.—Blood-red ladybeetle. Adult, left; pupa, center; larva, right. (From Bul. 183.)

Hippodamia convergens Guer.
(Convergent Ladybeetle)

This predaceous beetle is not nearly so common on the citrus aphid as on truck crop aphids

Fig. 115.—Convergent ladybeetle. Larva, left; pupa, center; adult, right. (From Bul. 183.)

but is occasionally found in both larval and adult stages. Its life history was found to be as follows: egg stage, three to five days; larval stage, 11 to 14 days; pupal stage, six days. The larvae eat an average of 56 aphids per day and adults eat an average of 84 aphids per day. No parasites were found but this beetle is often found dying in great numbers from what seems to be a bacterial disease.

Coccinella oculata Fab.
or
Olla abdominalis sobrina Csy.

This black beetle with a yellow spot on each wing, is an occasional citrus aphid predator. It lives quite well on the citrus mealy bug also. The life cycle is very similar to that of the other beetles and feeding records are similar. Eggs hatch in three to five days, larvae mature in two weeks and adults emerge in six days. The larvae eat an average of 17 aphids per day and the adults an average of 40. No natural enemies were observed in the field, but in the laboratory the larvae were very subject to a fungous disease caused by a species of *Cladosporium.*

Fig. 116. — Two-spotted ladybeetle. Larva, left; pupa, center; adult, right. (From. Bul. 183.)

Scymnus collaris Melsh.
Scymnus terminatus Say.

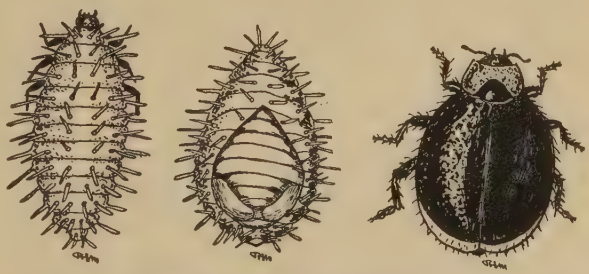

Fig. 117.—*Scymnus collaris* ladybeetle. Larva, left; pupa, center; adult, right. (From Bul. 183.)

Scymnus creperus fraternus Lec.
Scymnus brullei Muls.

These small black beetles are quite common but never abund-

ant. The larvae of some species are gray while others are covered with white, waxy tufts which make them resemble mealy bugs. Tiny pink eggs are deposited singly on infested leaves and hatch in two to four days. Young larvae pupate in eight days and emerge in five more. Larvae eat or rather suck out the juice of an average of 27 aphids per day and adults an average of 30 per day. The parasite, *Anistoylus similis,* subspecies *utahensis* Timberlake, was reared from *Scymnus collaris.*

Fig. 118.—*Scymnus terminatus.* Larva, left; pupa, center; adult, right. (From Bul. 183.)

Some of the minor ladybeetle predators of the citrus aphid are the following: *Chilocorus bivulnerus* Muls. (Twice-stabbed ladybeetle) ; *Rodalia cardinalis* Muls. (Vedalia ladybeetle) ; *Exochomus marginipennis childrenii* Muls.; *Microweisea coccidivora* Ash.; *Stethorous utilis* Horn.; *Delphastus pusillus* Lec.; *Zagloda* sp. (Near *hystryx); Exochomus latinsculus* Csy.; *Hyperaspis regalis* Csy.; *Hyperaspis binotata* Say.

Another ladybeetle imported from China through the California Experiment Station *(Leis* sp.) feeds quite ravenously on the citrus aphid. The Florida Agricultural Experiment Station has been attempting to establish this beetle in the state but at the present time it is not possible to state the degree of success *(28).*

FAMILY=TENEBRIONIDAE

Epitragodes tomentosus Lec.

(Downy Darkling Beetle)

This scale-feeding beetle was found to feed also on the citrus aphid. When caged with aphids, beetles collected from the field ate eight aphids per day. The life history of this predator was not studied.

ORDER=DIPTERA
FAMILY=SYRPHIDAE
(Syrphus Flies)
Baccha clavata Fab.

The black, slender-bodied, clear-winged adult fly deposits her elongated white eggs, singly, on leaves and twigs heavily infested with aphids. The eggs hatch in two to four days into tiny, maggot-like predators which eat an average of 33 aphids per day until their maturity. The larval stage lasts 11 days and then pupation takes place on a nearby leaf or twig. The adult emerges in four to five days, making the complete life cycle 17 to 20 days. Adult flies feed on pollen of flowers and honeydew in the field. In captivity the adults were kept alive for several days on sugar solutions. The larvae of this insect are heavily parasitized by *Diplazon laetatorius* Fab., *Syrphophagus 4-maculatae* Ashm., *Pachyneuron allograptae* Ashmead, *Pachyneuron syrphi* Ashm., and a Cynipid. Eggs, larvae and pupae were killed by a temperature of 26°F. during January, 1927, but according to W. L. Thompson most of them survived the same temperature during January, 1928.

Fig. 119.—Syrphus fly, *Baccha clavata.* Adult, left; pupa, center; larva, right. (From Bul. 183.)

Baccha lugens Loew.

The adult of this predator differs from

Fig. 120.—Syrphus fly, *Baccha lugens.* Adult, left; pupa, center; larva, right. (From Bul. 183.)

that of *Baccha clavata* only in that it has a smoky film on its wings and abdomen. The eggs are laid singly on aphid infested twigs and hatch in one to three days. The snail- or slug-like larvae live six to eight days, eating an average of 35 aphids per day, then pupate. The adult emerges in 7 to 8 days. Natural enemies of this predator reared were *Diplazon laetatorius* Fab., *Syrphophagus 4-maculatae* Ashm., and *Pachyneuron syrphi* Ashmead.

Allograpta obliqua Say.

The yellow banded, slender-bodied adult fly with obliquely marked abdomen is common on citrus aphids during the cooler season. During the summer none of this species were found on citrus aphids but were common on truck crop aphids. The elongate, white eggs, laid singly on aphid infested leaves and twigs, hatch in one to three days. The light green larva with white markings eats an average of 34 aphids per day and pupates in

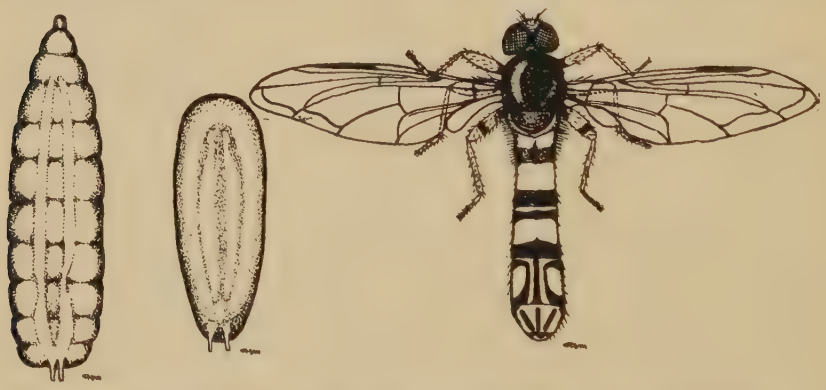

Fig. 121.—*Allograpta obliqua* Say., a predator of the citrus aphid. Adult, right; pupa, center; larva, left.

10 to 14 days. The adult emerges in six to eight days. Parasites of this predator are *Diplazon laetatorius* Fab. and *Pachyneuron allograptae* Ashmead.

Syrphus wiedemanni Johns.
(Syrphus americanus Wied.)

Another winter predator of the citrus aphid is this common, yellow banded, plump-bodied fly, *Syrphus wiedemanni* Johns. The elongate, white eggs are laid singly on infested twigs and leaves and hatch in three to four days. The light brown, maggot-

like larvae eat an average of 45 aphids per day and pupate in 14 days. The adult emerges in from eight to eleven days. Parasites reared from these larvae were *Diplazon laetatorius* Fab., *Pachyneuron syrphi* Ashm. and *Syrphophagus 4-maculatae* Ashm.

FAMILY=AGROMYZIDAE

Leucopis americana Malloch

This tiny, gray fly, found hovering around aphid colonies, is there to deposit her minute, white eggs on the infested leaves and twigs. The eggs hatch in from two to three days into very small, dirty white maggots with two horns on the posterior end. These larvae eat an average of 17 aphids per day and pupate in eight days. Adults emerge in five to eight days more. One hymenopterous parasite, a Cynipid, was reared from this predator.

ORDER=NEUROPTERA

(Lacewing Flies)

FAMILY=CHRYSOPIDAE

(Green Lacewing)

Chrysopa harrisii Fitch.

This delicate, green, lacywinged adult deposits her eggs singly on a silken thread, spun from the anal gland. The eggs hatch in three to five days into slender, white larvae with powerful jaws. These larvae eat an average of 28 aphids per day for 14 days, then spin a spherical silken cocoon with their anal glands and there pupate. Ten days later the emerging insect cuts a round door in the cocoon and crawls out. On the top of the cocoon the adult emerges, leaving behind the old pupal skin. This lacewing fly was parasitized by *Chrysopoctonus chrysopae* Ashm.

Chrysopa sp. (Near *lateralis)*

(Trash Bug)

In all respects this predator is similar to the one immediately preceding except that in the larval stage the young cover themselves with dead aphid skins and any other convenient trash. This trait has won for them the name of "trash bug" and they certainly resemble an animated trash heap.

FAMILY=HEMEROBIIDAE
(Brown Lacewing)
Micromus posticus Walker

The brown, slender-bodied lacywinged adult sticks her yellow eggs, singly and flat, on the leaf. These hatch in two to three days and the dark red, slender larvae mature in five to seven days. At pupation a very light, flimsy web is spun in a curled leaf or crotch of two branches and, suspended in this, the pupal form remains for seven days. It then crawls out and the adult emerges. This predator is common only during the summer months. No parasites were reared from this predator.

ORDER=HEMIPTERA
FAMILY=REDUVIIDAE
Zelus bilobus Say.
FAMILY=PHYMATIDAE
Phymata erosa Guer.

These two bugs are found to feed occasionally on the citrus aphids. They prefer larger prey however, especially flies and other soft bodied insects, but in some cases they were found to eat many aphids.

FAMILY=ANTHOCORIDAE (Flower-bugs)
Triphleps insidiosus Say.

Nymphs and young of this small bug can frequently be found with young aphids on the end of their beaks. They are never abundant among aphids but are quite common. This insect is also a common predator of thrips.

PARASITES

ORDER=HYMENOPTERA
FAMILY=BRACONIDAE
Lysiphlebus testaceipes Cres.

This small wasp, which is very beneficial in the control of other aphids, is somewhat unfortunate in the case of the citrus aphid. The adults are usually quite common among the aphid colonies. They proceed to travel over the infested leaves and puncture the young aphids with their ovipositors. These nymphs reach maturity and may or may not produce young. In most

cases none are produced but occasionally one or two may be found. Ten days after the aphid is punctured by the wasp the aphid's body turns yellow, one day later it is a very dark red and still later it becomes almost black. When these are dissected the dead larva of the parasite can be found inside the old skin of the aphid. In many trials the writer has never been able to get an adult parasite to emerge from the citrus aphid, however Dr. F. R. Cole *(5)* states that at Orlando, Florida, from 1 to 10 percent of the citrus aphids were attacked by the parasite and the adult successfully emerged. This difficulty is certainly very detrimental to the increase of the parasite for the citrus aphid merely acts as a "trap crop" for the parasite.

Colonies of *Aphis gossypii* and *Toxoptera aurantiae,* from which this parasite can successfully emerge are frequently entirely destroyed in three weeks by this active wasp.

FUNGOUS DISEASES

Three diseases have been reported by Dr. E. M. Gilbert and W. A. Kuntz *(7)* as attacking the citrus aphid. They include an entomophthora, *Empusa fresenii* Nowak., first reported by

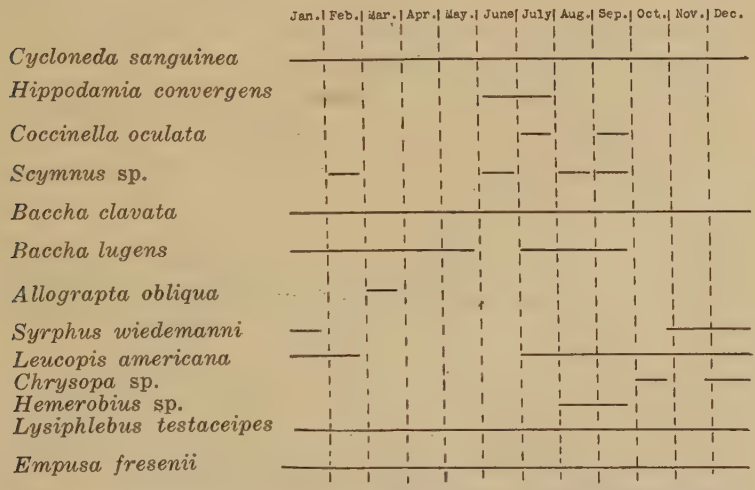

Fig. 122.—Occurrence of various aphid predators and parasites during the year 1926-27 at Lake Alfred, Florida.

Dr. E. W. Berger, entomologist of the Florida State Plant Board; an olive brown mold, *Cladosporium* sp., and a white mold, *Cephalosporium* sp. Of these three diseases, *Empusa fresenii* is by far the most common and most beneficial. *Clado-*

sporium is now considered as a saprophytic organism which attacks only dead aphids. *Cephalosporium* is effective on some truck crop aphids where the plants grow near the ground but is not efficient in a citrus tree to any appreciable extent.

The fungus, *Empusa fresenii,* is found wherever aphids are found and during the entire season. It seems to be more effective during periods of high humidity and in colonies of aphids that are old and densely populated.

Summary of Biological Control.—The number of aphids destroyed per day by each predator is given below:

	Aphids Destroyed Per Day		
	Larva	Adult	Average
Cycloneda sanguinea	16	65	26
Hippodamia convergens	56	84	61
Coccinella oculata	17	40	21
Scymnus sp.	27	30	20 ?
Baccha clavata	33	....	33
Baccha lugens	35	....	35
Allograpta obliqua	34	....	34
Syrphus wiedemanni	45	....	45
Leucopis americana	17	....	17
Chrysopa sp.	28	....	28
Hemerobius sp.	20	....	20
Lysiphlebus testaceipes	actual number found		
Empusa fresenii	actual number found		

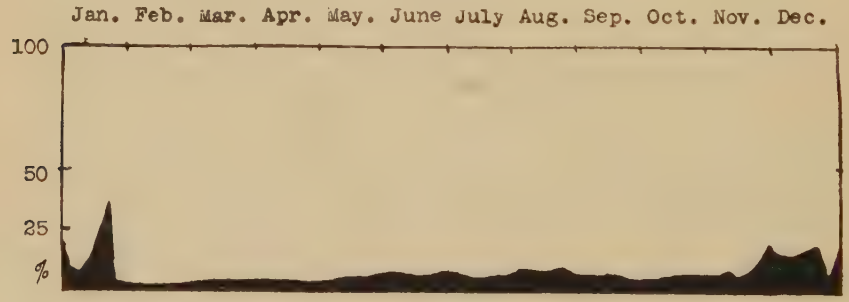

Fig. 123.—Percentage of aphids destroyed by all natural enemies.

As can be seen from Fig. 123 the predators and parasites aid greatly in controlling the aphid when the aphid population is at a standstill or decreasing but when the aphids are thriving, the natural enemies are not able to control them.

ARTIFICIAL CONTROL

The first complete report on control work against the green citrus aphid in Florida was given by Professor J. R. Watson and Mr. A. H. Beyer *(23)*. This paper reports good success by spot

dusting or dusting only the infested twigs in a grove. Directions are given for making a good dust of nicotine sulphate and lime. They also state that infested twigs on young trees can be dipped successfully in a solution of nicotine sulphate-soap solution with a good kill as a result. It is suggested that spraying will give good results if done before the leaves are badly curled but if delayed will not be successful. In this case a power duster must be used.

In a later article Professor Watson *(28)* reports good success by using a hood attached to the side of a power duster for making applications in a light wind. See Fig. 121. In a previous paper the writer *(11)* reported success by using snuff as a dust on wet foliage.

Mr. W. W. Yothers and Mr. O. C. McBride *(33)* report that dusting with a 3 percent nicotine sulphate dust is much more successful when the conditions are warm (73° F.) and calm rather than when cool (60° F.) and calm or cool and windy.

In the work carried on by the writer an attempt was made to use all insecticides and methods available. This work is reported in the following discussion.

METHODS

A great variety of insecticides have been used against the green citrus aphid. These insecticides were used at various strengths and in combination with various spreaders. Not only were the materials varied greatly but considerable attention was given to the time and method of application. Spraying with both hand apparatus and power machinery was used, and dusting by hand and with a power duster was used in the open and under tents.

Dipping and Spraying.—When a small tree or a few low, accessible branches of a large tree are severely infested, the aphids can be very effectively killed by dipping the infested part into a mixture of an effective insecticide. When twigs are dipped they should be thoroughly swished around in the liquid to insure wetting all aphids. Spraying is quite effective if done thoroughly and before the leaves are curled. The spray material must hit the aphids to kill them, so a high pressure and proper manipulation of the gun or rod and nozzle are very essential.

Dusting and Fumigation.—Dusting is the most rapid method of securing a thorough control if a suitable time can be found

for the work. Wind enough so that one can tell the direction it is blowing is too much. To avoid this objection, dusting under tents, varying in size from 4-foot wire cones, covered with

Fig. 124.—Dusting apparati and oil damage. A. Power duster with tent attachment. B. Home-made dust mixer. C. Typical oil damage to tender citrus leaves. D. Typical oil damage to tender citrus twigs.

paraffined cloth, to 40-foot California fumigation tents was attempted. This method is quite thorough but slow and expensive. A tent-like apparatus was devised and attached to the side

of the power duster so that it could be drawn over the row as it was dusted. This method proved quite satisfactory when a light wind was blowing. See Fig. 124.

Insecticides Used.—In using the following materials all insecticides were used on a small scale for the first few tests. If some one of the materials appeared to be promising it was used in the power apparatus on a large scale. The sprays were used both as dips and in the hand sprayer. The dusts were used in open dusting and fumigation under tents.

In making observations as to kill of aphids and effect on foliage a 24-hour period was always allowed between the time of application and the time of checking results. The percent of kill was based on the total number of aphids found dead and alive after the application. In cases where the aphids dropped from the twigs when they were killed, counts were made on marked twigs before the application was made. The strength of mixtures used is given in percent of the total insecticide or concentrate in the mixture.

OIL EMULSIONS

In spraying oil emulsions on citrus foliage it is very difficult to wet the foliage. The emulsion does not usually spread but gathers in drops. In many cases of burning one can get the same condition by spraying clear water on the trees during a period of high temperature and humidity.

Oil emulsions used as insecticides kill most of the aphid predators. When the plant extracts are used these predators are usually not injured. Fig. 124 shows typical oil burning on tender citrus foliage.

PLANT EXTRACTS

DERRIS

This material is not toxic to plants when used at any of the ordinary spraying strengths. When used against aphids at 1 part to 800 it gave a 99 percent kill and at 1 part to 1,000 it gave a 95 percent kill. This insecticide however, is a slow acting material and will not kill all the aphids in 24 hours but in 36 to 48 hours it shows its real effectiveness. The writer was not able to find that derris extracts had any more lasting effect or repellant action than did nicotine sulphate.

NICOTINE SULPHATE

Another plant extract known as nicotine sulphate is one of the oldest and best aphicides. This material is dark brown, almost black, in color and flows like syrup. It contains 40 percent nicotine sulphate and 60 percent inert matter. It must be mixed with soapy water, ½ to 1 percent, to get an effective killing liquid. This mixture is chocolate brown in color and has a very penetrating odor.

Nicotine sulphate does not injure foliage at any spraying dilution. When used against the citrus aphid at the strength of 1 to 800 in a ½ to 1 percent soap solution it gave a 99 percent kill. More soap is occasionally necessary if the water is extremely hard.

One very distinct advantage of this material is the fact that it makes a very effective dust. When the liquid is poured into lime and the whole mass agitated for several minutes a very effective dust results. Seven and a half pounds of nicotine sulphate are necessary per 100 pounds of lime for a 3 percent dust. A home made mixer as shown in Fig. 124 is very satisfactory. An especially fine dust was made by using lime and sulphur in equal parts for the carrier. This dust stuck to the foliage better than when lime alone was used and was more effective when used against the citrus rust mite.

Nicotine sulphate dusts at 1 percent gave a 37.8 percent kill, at 2 percent a 99 percent kill and at 3 percent a 99.8 percent kill of the citrus aphid.

PYRETHRUM

The liquid extract of the flowers of pyrethrum was used against the citrus aphid with good result. This asphalt like sample was first dissolved in alcohol and aliquot parts taken. These were mixed with soapy water and formed a chocolate colored mixture.

This material was not toxic to plants in any ordinary spray dilution. When used against the citrus aphid at 1 part to 800 of water containing 1 percent soap a 90 percent kill was accomplished. With water containing 2 percent soap a 98 percent kill was accomplished.

MISCELLANEOUS INSECTICIDES

LIME-SULPHUR

This common insecticide and fungicide was used at various strengths. It burned tender foliage when used at stronger dilutions than 1 to 60. When sprayed on the citrus aphid it dried on the backs of the insects without doing them any harm. Aphids that had been thoroughly washed or almost drowned in the solution were killed. After three days an examination showed a few dead aphids but this number was not important.

SNUFF

Three grades of finely ground tobacco stems, or snuff, were used both as a dust and in suspensions. These materials are made from waste tobacco products and the grade depends on the degree of fineness of the particles. This material contains 2 percent nicotine.

None of these materials damaged the tender citrus foliage. When dusted on dry citrus aphids at full strength no kill was accomplished but if used when the aphids were wet with dew a 95 percent kill resulted. Snuff was mixed with water at the rate of 15 pounds for 50 gallons and used as a dip and in a hand sprayer. This mixture gave a 90 percent kill but could not be used in a power machine.

Snuff mixed with anhydrous calcium chloride was used with good results as to kill but the calcium chloride damaged the foliage. This material was also quite destructive to the duster in which it was used. Snuff and sulphur mixed in equal parts was not effective as an aphicide.

FISH OIL SOAP

The dark brown color and fish odor of this material will serve to identify it anywhere. It was found to contain 50 percent moisture. When mixed with water it formed a muddy mixture of suds. When used above 3 percent this soap caused the very tender twigs to be burned and to drop off but below that dilution no injury resulted. When used at ½ percent a 17 percent kill was obtained, at 1 percent a 71 percent kill resulted, and at 2 percent a 93 percent kill resulted.

The greatest use for this material is not as an insecticide itself but as a spreader for other materials. When used with oils or plant extracts, as stated before, it increases their efficiency many times.

SUMMARY OF INSECTICIDAL WORK

Material	Percent Emulsion	Effect on Tender Citrus	Percent Citrus Aphids Killed
Aldehol S.—			
Alone	3½	No injury	97
With F. O. Soap ½%	1	No injury	96
Oil Emulsion No. 1 (75% oil)	1	No damage	63.4
	2	Leaves curled and dwarfed	93.7
Oil Emulsion No. 2 (65% oil)	1	No damage	Less than 50
	2	At high temp. brown spots where drops stood	Less than 50
Oil Emulsion No. 3 (65% oil)	1	No damage	Less than 50
	2	No damage	72.7
	3	Few tips slightly burned	84.1
Pine Oil G1 (48% oil)	2	No damage	Less than 50
	3½	No damage	98
Pine Oil G2 (48% oil)	2	No damage	Less than 50
	3½	No damage	99
Pine Oil G4 (63% oil)	2	No damage	Less than 50
	3½	No damage	96
Pine Oil G5	2	No damage	37
	3½	No damage	99
Pine Oil No. 8 (42% oil)	2	No damage	25
	3½	No damage	75

SUMMARY OF INSECTICIDAL WORK—Continued

Material	Percent Emulsion	Effect on Tender Citrus	Percent Citrus Aphids Killed
Renol	1	No damage	5
	2	No damage	86
	3	No damage	91
Oil Emulsion No. 4 (65% oil)	1	No damage	Less than 50
	2	No damage	Less than 50
Oil Emulsion No. 5 (65% oil)	1	No damage	Less than 50
	2	No damage	Less than 50
Shale Oil (58% oil)	1	No damage	Less than 50
	2	No damage	65
	3	No damage	85.8
Oil Emulsion No. 6 (85% oil)	1	No damage	95
	2	Occasional leaf spotted	96
	3	Occasional leaf spotted	98
Derris compound	1–800	No damage	99
	1–1,000	No damage	95
Nicotine Sulphate—			
½% F. O. Soap	1–800	No damage	99
Nicotine Sulphate Dust	1	No damage	37.8
		No damage	99
		No damage	99.8
Pyrethrum and—			
F. O. Soap 1%	1–800	No damage	90
F. O. Soap 2%	1–800	No damage	98

SUMMARY OF INSECTICIDAL WORK—Continued

Material	Percent Emulsion	Effect on Tender Citrus	Percent Citrus Aphids Killed
Calcium Cyanide No. 1—			
Open	100	Occasional severe damage	Less than 50
In Tents	100	Occasional severe damage	99
Calcium Fluosilicate	100	No damage	None
Calcium Cyanide No. 2 plus 15% sulphur	100	Occasional severe damage	50
In tents	100	Occasional severe damage	99
Cocotine alone	3p.–100g.	No damage	5
	6p.–100g.	Severe injury	50
In ½% F. O. Soap	3p.–100g.	No damage	90
	6p.–100g.	Severe injury	98
Lime Sulphur 32 Baume	1–40	Many leaves burned	None
	1–60	No damage	None
Naphthalene	100	No damage	None
Snuff—			
Dry foliage	100	No damage	None
Wet foliage	100	No damage	95
Suspension	15 lbs. to 50 gal.	No damage	90
Fish Oil Soap	½	No damage	17
	1	No damage	71
	2	No damage	91

SUMMARY

A new aphid of citrus, *Aphis spiraecola* Patch, has occurred in Florida during the last few years and has been quite destructive. This aphid was known to attack spiraea in the northern United States but was not found in Florida until 1923.

In Florida this aphid can live on a great number of host plants but thrives only on tender growth on citrus, spiraea and apple. Other plants however serve as "overflow" hosts and aid in carrying the aphid over between flushes of tender growth on citrus. All varieties of citrus are attacked but those that grow most slowly and continuously are most severely damaged. Attacked trees become dwarfed, the leaves are curled, the amount of fruit set is small and in general the tree is in a poor state of growth.

The green citrus aphid reproduces asexually during the entire year at Lake Alfred while eggs are deposited in the northern part of the state. The average length of life for the year August, 1926 to August, 1927 was 16.7 days for 198 females. The longest life recorded was 49 days during December and January. The nymphal period ranged from 4 to 16 days, being longest during the winter and shortest in September. The average nymphal period was 6.93 days for 198 females. The rate of reproduction was greatest at a temperature of 75 to 80 degrees and averaged 29.11 for 198 females. The maximum number produced per day by one female was 16.

Aphids fed in crowded conditions or on hardening foliage produce many winged forms while if fed on tender growth separately, no winged forms appear. The citrus aphid reacted very little to gravity, concentrated under the shade produced by cheesecloth, concentrated at the temperature 72° to 93° F. and in captivity were slightly attracted to their preferred host plants. Aphids lived twice as long when subjected to 100 percent humidity as when humidity was low. A large number of insects were found feeding on the honeydew secreted by the citrus aphid.

A great number of natural agencies tend to control the citrus aphid but none of these are efficient enough to make artificial control unnecessary. Rain, wind and changes of temperature are all destructive under some conditions. Many species of ladybeetles and syrphus fly predators as well as lacewing flies and others were observed but none of these were able to do more than partially check the aphid increase. One hymenopterous parasite attacks the citrus aphid but is not generally able to

emerge successfully from the aphid's body. A fungous disease is ever present but during 1926-27 was of little value as a control.

This pest can be successfully controlled by either spraying or dusting if done thoroughly and in good time. In general, oils were not satisfactory aphicides but some seem quite promising. Extracts of derris and nicotine sulphate were most successful and gave the most consistent control.

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AUTOBIOGRAPHY

I, Ralph Lester Miller, was born near Cincinnati, Ohio, May 29, 1902. All of my elementary school training was received in a rural school in Hamilton County and my secondary school work in Cincinnati, Ohio. I entered The Ohio State University in 1920 and received the degree of Bachelor of Science in Agriculture in March, 1925. A Fellowship at the Ohio Agricultural Experiment Station at Wooster, Ohio, was then accepted and I began graduate work, receiving the degree of Master of Science in December, 1925, after having spent six months at Wooster, Ohio, and three months at The Ohio State University.

In January, 1926, I accepted a position as Assistant Entomologist of the Florida Agricultural Experiment Station and remained at Lake Alfred, Florida, until October 1, 1927. At that time I began residence work at The Ohio State University on a University Fellowship and received the degree of Doctor of Philosophy in June, 1928.